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# THE SAR CRITERIA AND FORCE ANALYSIS

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DEPARTMENT OF TRANSPORTATION



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THE SAR CRITERIA AND FORCE ANALYSIS

FINAL REPORT

8 NOVEMBER 1971

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# PREFACE

The SAR Criteria and Force Analysis (SC&FA) was initially conducted under the direction of CAPT NORMAN P. ENSRUD for the years 1967-1970, subsequent efforts have been directed by CAPT PAUL W. MEYER. Full or part-time participants included:

CDR Richard T. PENN, Jr. (11/67-6/69)
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LT Robert J. HEID (1/68-5/70)
LT Gerald L. UNDERWOOD (11/69-6/71)
LTJG Ronald K. LOSCH (2/71-10/71)
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Mr. Paul J. D'ZMURA (2/68-8/69; 7/71-11/71)
Mr. Harry F. GREGG (6/68-6/69)
Mr. Ronald G. McGEE (9/68-6/70)

As a result of the SC&FA, three major decision making tools have been provided to Coast Guard management; namely the Long Range Forecasts of Activities in the Marine Environment (MAF); the Shore Station Analytical Model (SSAM), and the Search and Rescue Simulation (SARSIM). Documentation of the SSAM and SARSIM has been completed and distributed within Headquarters. The Marine Activities Forecast has been distributed by Commandant's Notice 5010, dated 22 September 1971.

Documentation of the Search and Rescue Simulation includes the following:

Volume I Executive Level Documentation

Volume II Analyst Level Documentation

| | |
|---|---|
| Volume III | Programmer Level Documentation for "PREPROCESSOR" |
| Volume IV | Programmer Level Documentation for "OPSIM" |
| Volume V | Programmer Level Documentation for "POSTPROCESSOR" |
| Volume VI | Validation |
| Appendix A | Flow Charts for Programmer Level Documentation |
| Appendix B | Program Listings for Programmer Level Documentation |

These documents, along with the Shore Station Analytical Model documentation are available for review in the Plans Evaluation Division (CPE), the Search and Rescue Division (OSR), and the Operations Plans Staff (OS).

It should be noted that Chapter II makes liberal use of the model descriptions and summary data contained in SARSIM's Executive Level Documentation and the Executive Summary section of the Marine Activity Forecast.

# CHAPTER I - GENESIS

This is the final report of the SAR Criteria & Force Analysis Study (SC&FA). This multi-year effort has given form and substance to the SAR decision making process. The study has developed and delivered several decision making aids to the program manager so that he can now examine, on an integrated basis (i.e., aircraft, cutters, and shore stations), the probable outcome of alternative search and rescue resource allocations. Intrinsic to such examinations are: (1) refined projections of future demand, (2) consideration of alternative manning, readiness and maintenance policies, and (3) comparison of results with cost and effectiveness criteria synthesized by the program manager.

Upon review of the 1967 Aviation Issue Paper the Commandant was concerned about the lack of a dynamic, integrated, analytical approach to the above considerations. It was this concern that initiated the SC&FA. The tools provided by the study permit the decision process to become:

- dynamic in that it can change over time, especially in an anticipatory rather than a reactive manner.

- integrated from the standpoint of considering more than one resource type.

- substantially analytical in that most system components are quantitatively examined for their relationships with each other in the context of the whole. The qualitative judgment of the decision maker is required for those components that resist rigorous analysis.

The thrust of the process is to assist the decision maker to understand the effects of his decisions. However, it remains an aid to, not a substitute for, the program manager. From the inception of the study close liaison with the program manager has been maintained with a view toward developing tools that would improve the SAR decision making process.

Three tools have been developed and delivered. The first, called the Shore Station Analytical Model (SSAM), calculates minimum acceptable crew readiness postures for individual stations. It is based on historical SAR data adjusted for expected changes in SAR workload. Insight to such expected changes is provided by the second tool, the Marine Activities Forecast (MAF). While especially valuable to the SAR program manager, this forecast also provides valuable input to other program areas. The Search and Rescue Simulation (SARSIM) is the third and most significant decision making aid developed by the study. This comprehensive computerized model is the mechanism for determining the probable outcomes of the joint location and use of different types of resources for an entire district. These outcomes can then be compared with SAR system cost and effectiveness criteria.

Chapter II of this report provides a general description of the SSAM, MAF, and SARSIM and the decision making information supplied by each aid.

Chapter III describes our current perception of a dynamic SAR decision making process including the integration of the three tools into that process.

Chapter IV points out areas in which further analysis is needed in order to realize the full potential of the SAR decision making process.

Annex A provides a synopsis of the three previously published interim reports.

## CHAPTER II - THREE NEW SAR DECISION MAKING TOOLS: INPUT-OUTPUT DESCRIPTION

### A. Long-Range Forecasts of Activities in the Marine Environment

The Marine Activities Forecast (MAF) was developed under Coast Guard contract, by the National Planning Association's Center for Techno Economic Studies. The study provides forecasts thru 1980 of various kinds of activities in the marine environment and makes certain implications for Coast Guard search and rescue planning.

Because operational requirements for search and rescue services differ substantially among coastal regions, separate forecasts have been made for each of twelve regional areas. By using the same systematic methodology for each forecasting effort, uniformity of approach was assured.

An auxiliary benefit of the Forecast is its applicability as a planning document for other Coast Guard mission areas. The MAF does not merely gather data and forecast from historical trends alone; it tempers data extrapolation with socio-economic considerations of those items that have or will have an influence on marine activity. Some examples are:

1. oceanography,
2. marine research and development,
3. leisure time activity,
4. commercial fishing,
5. aquaculture development,
6. marine mining,
7. marine transportation, and
8. ecology.

Consideration of this full spectrum of diverse factors provides a firm foundation for planning. The MAF analysis of these factors has resulted in predictions of future marine activity levels.

Figures II-1, 2, and 3 are examples of how these forecasts are presented. The first shows a projection of total responses and a breakdown by clientele category. The second shows total responses subdivided by the type of assisting resource. The third shows the expected trend for each of the twelve regions.

It should be noted that the figures represent point estimates and could vary up or down. As the decade progresses additional information will be available and better estimates can be made.

The potential user of the forecast is well advised to heed the author's caveat to look behind the projections at the data and assumptions used. There are three alternative courses of action open to the user: (1) accept the forecast in its present form, (2) gather additional data and make new projections using idential assumptions, or (3) using the same data, ascertain the effects of one or more alternative sets of assumptions. Generation of any alternative forecasts can be accomplished at a fraction of the costs incurred in developing the original Forecast.

The projection adopted becomes a vital ingredient of both the Shore Station Analytical Model and the Search and Rescue Simulation.

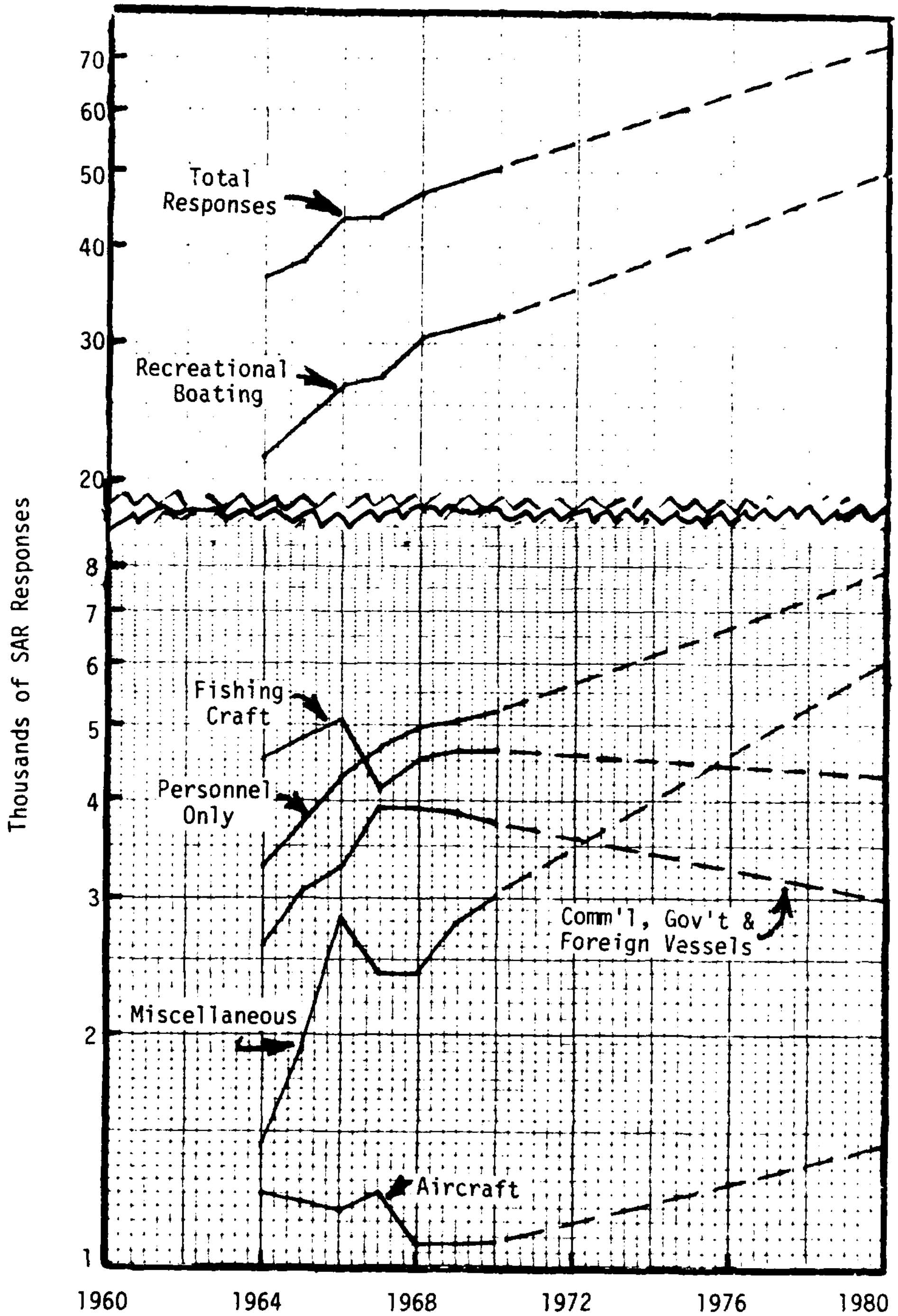


FIGURE II-1

U.S. trends and forecasts of search and rescue responses by the Coast Guard for different classes of activity, FY 1964-80.

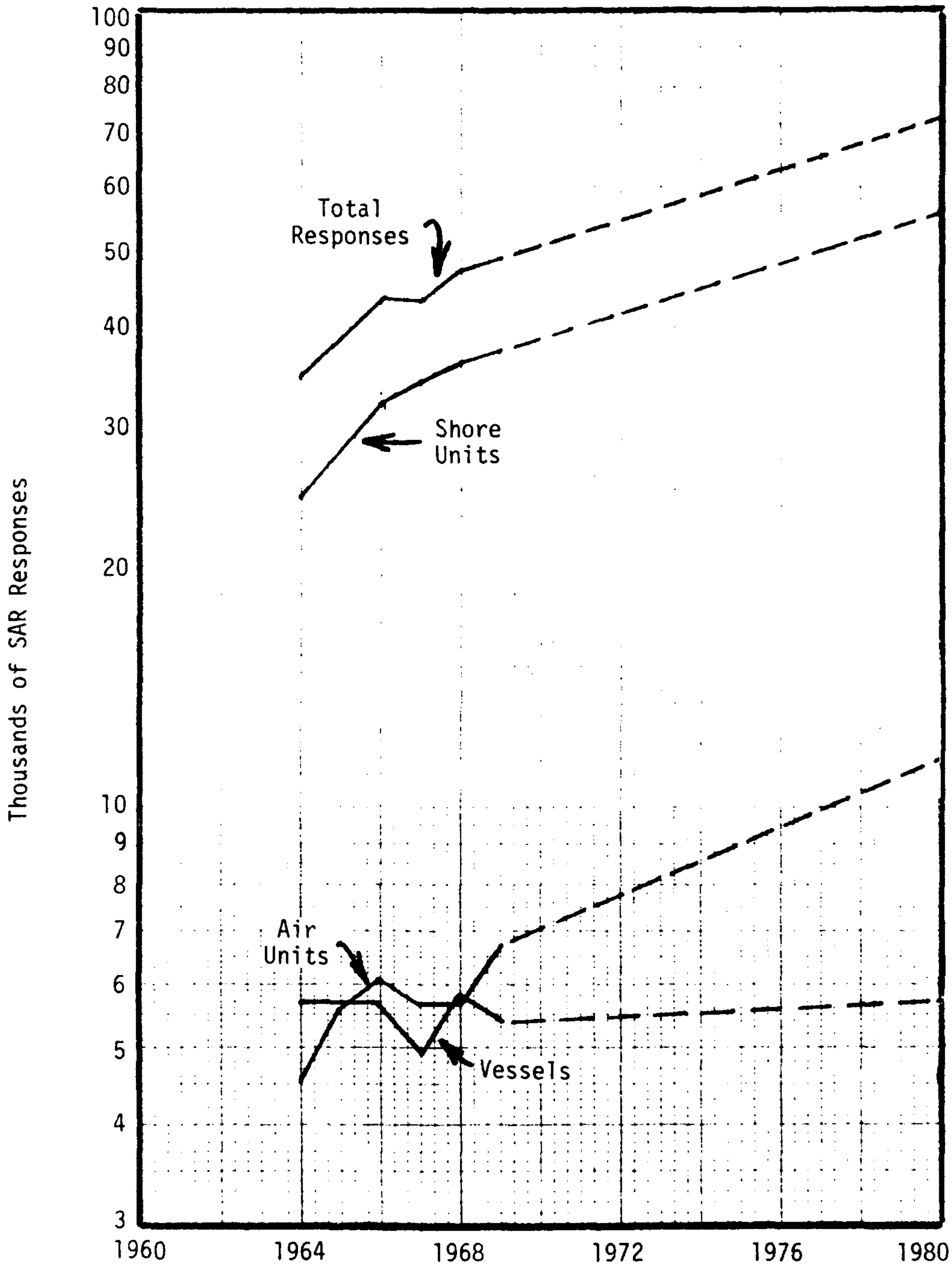


FIGURE II-2

U.S. trends and forecasts of search and rescue responses to all activities by air units, shore units, and vessels of the Coast Guard, FY 1964-80.

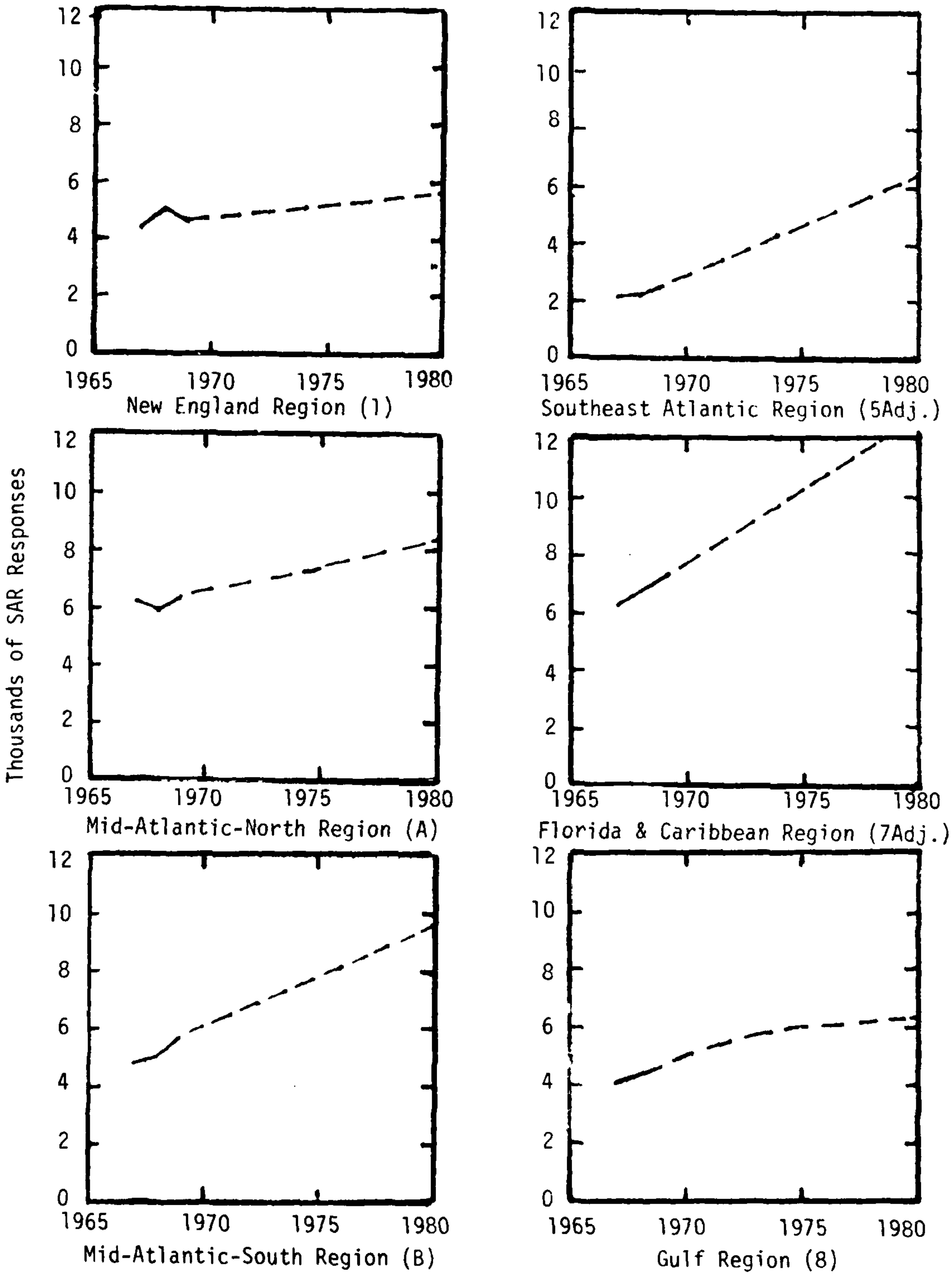


FIGURE II-3

Trends and forecasts of search and rescue responses to all activities by the U.S. Coast Guard for 12 coastal regions, FY 1967-80.



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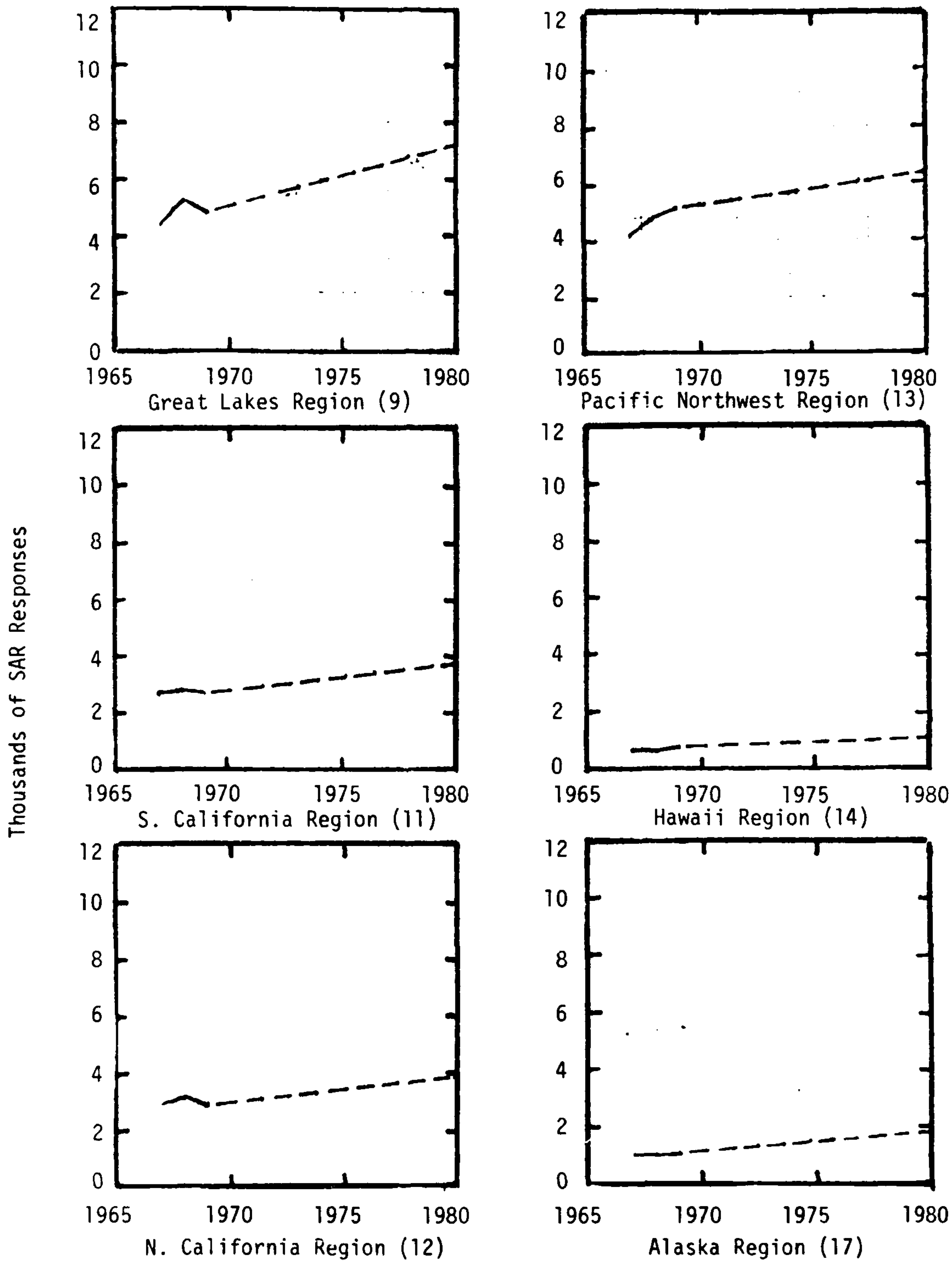



FIGURE II-3 (Cont'd)

## B. SHORE STATION ANALYTICAL MODEL

During the SAR Criteria and Force Analysis a great deal of effort was devoted to the determination of readiness postures at the shore stations, because in aggregate they account for a large percentage of the operating cost associated with the Search and Rescue Program. It was found that most stations maintained a readiness posture consistent with being able to satisfactorily handle the heaviest workload situation previously encountered or envisioned. Readiness levels based on such a "worst case" philosophy may result in gross misuse of personnel resources. The manpower overload thus created was reduced by analyzing the situation using an adaptation of classical queuing theory. This adaptation determines the appropriate readiness postures necessary to respond to a specified workload that varies daily, weekly and seasonally. It is called the Shore Station Analytical Model.

It was developed with the assumption that some small risk must be accepted because ultimately the demand for SAR forces will exceed even our "worst case" posture. The model is a probabilistic one in which the parameters are conservatively estimated. It quantifies the SAR manpower requirement for shore stations and estimates the percentage of time the resources will be utilized. The model does not consider other mission requirements. Further, it analyzes each station as an independent entity and thus the effects of interaction with adjacent stations are not included.

Figure II-4 illustrates how the SSAM can be used to determine an appropriate readiness posture for specified shore stations. The SSAM utilizes three major inputs; namely; (1) historical workload, (2) growth

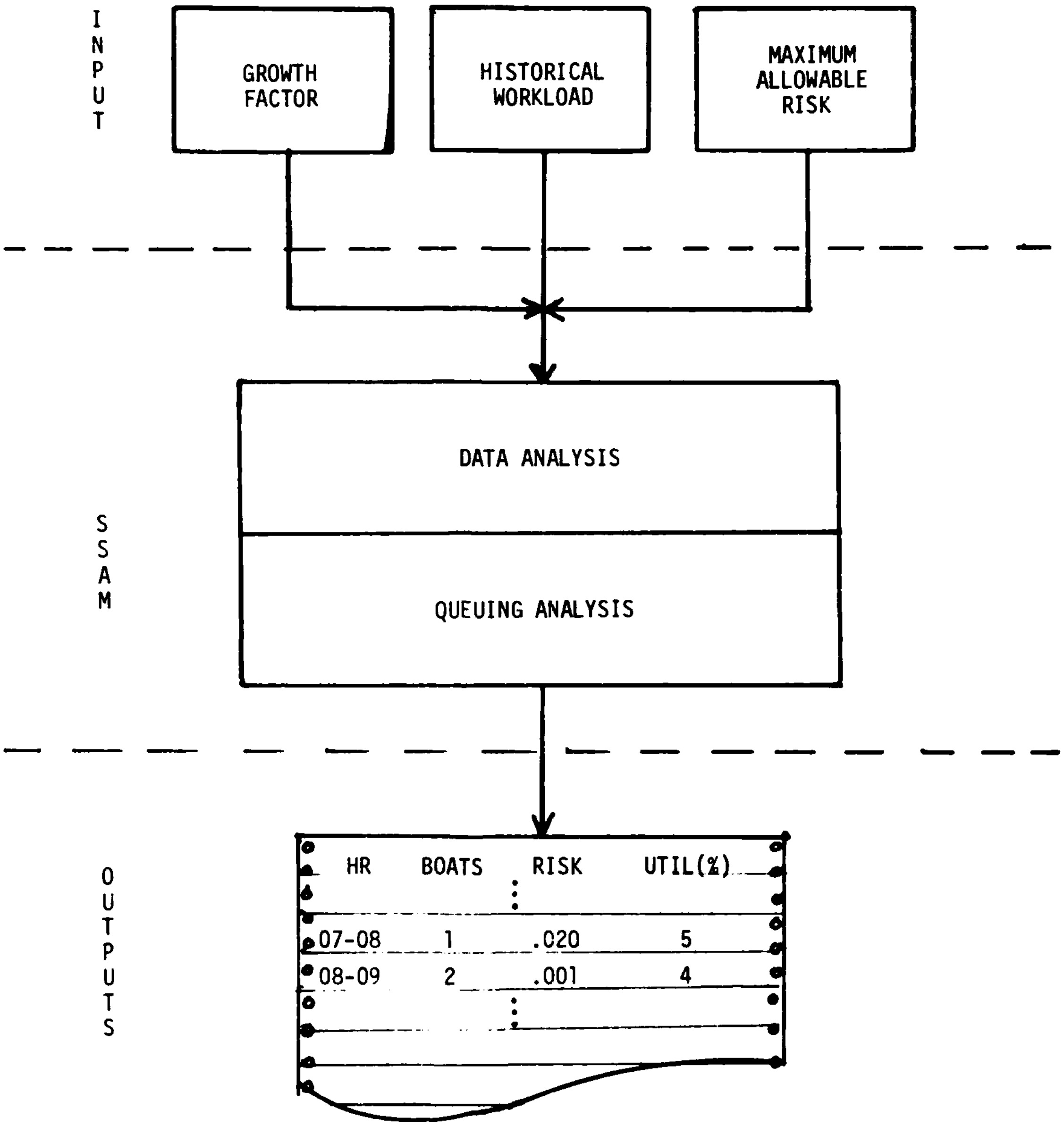



Figure II-4

Shore Station Analytical Model: Inputs and Outputs

factor and (3) maximum allowable risk (MAR). The historical workload is obtained from the SAR data files. Growth factor is determined from the Marine Activities Forecast (MAF). In some cases, local knowledge or past experience may adjust the MAF growth factors. Maximum allowable risk (MAR) is the maximum probability, acceptable to the program manager, that any serious case will not receive immediate CG response (i.e., a serious case will wait). In this respect, the model is very conservative because each serious wait is considered adverse without regard to the length of that wait. Analysis has shown that even some serious cases can tolerate a short delay in receiving service.

These inputs are initially examined in the data analysis phase to determine the workload for each hour of the day. The severity level and other factors, used to determine the risk associated with a readiness posture, are also calculated in this phase.

The queuing analysis phase uses the hourly workload developed in the previous phase to determine the hourly boat readiness posture required to keep the risk equal to or less than the input specified maximum allowable. The output shows tne boat readiness posture, underway crew utilization, and risk for each hour of the day.

The SSAM provides the program manager with an analytical means of determining the readiness posture necessary to respond to something less than the most extreme or "worst case" situation previously encountered or anticipated. The concept of maximum allowable risk permits the decision maker to plan for shore station resources "...within a framework of acceptable tolerance..." as articulated in the Long Range View approved by the Commandant.

The SSAM provides the manager with useful and heretofore unobtainable

decision making information. However, it must be acknowledged that the model's use is limited by several critical factors. The model does not:

(1) Consider the use of other resource types to also respond to SAR incidents.

(2) Operate efficiently for stations with low seasonal workloads, i.e., less than 34 serious cases.

(3) Consider the possible effect standby servers (crews) may have on readiness posture.

For these reasons, but more importantly because the program manager's need for more decision making information is essential, an integrated, multi-resource, search and rescue simulation model (SARSIM) was developed.

## C. SEARCH AND RESCUE SIMULATION (SARSIM)

SARSIM is a tool with which the manager may examine the likely effects of conceived changes to the SAR System. This examination is accomplished by comparing alternative runs of the model with one another and against a set of minimum acceptable system performance standards. Such changes might involve decisions concerning:

(1) establishment, relocation or disestablishment of shore stations or air stations within a Coast Guard district;

(2) changes in manning levels at individual stations or throughout a district;

(3) relocation of resources from one station to another or other changes in the relative mix or availability of different kinds of resources; or

(4) introduction of new types of resources, either as replacements for or in addition to existing resources.

SARSIM was developed by an interdisciplinary team of analysts and programmers of the National Bureau of Standards (Technical Analysis Division) with the active participation of Coast Guard representatives. This joint effort produced a reasonable and valid representation of the search and rescue process (system), including the crucial factors which affect the provision of services required at random in real life. The model takes into account physical locations of stations and resources; capabilities and characteristics of resources; policies affecting selection of resources to be assigned to cases, manning levels for shifts and vehicles, and acceptable levels of service provided; and weather and sea conditions. In addition, the nature and rate of arrival of case loads can be based on historical precedents or varied at the discretion of the user.

Special care was taken during development of the model to insure that characteristics of simulated cases and services were realistic and internally consistent, and that the processes simulated reflected the same order and similar detail as those encountered in reality. Some simplifications were, perforce, required for the sake of economy and ease of operation, but artificialities have been kept to a minimum. Any such departures from reality have been approved by the program manager.

In simplest terms, the SARSIM represents a typical queueing problem wherein customers (i.e., cases requiring Coast Guard services) enter the system at random times to be serviced by one or more CG facilities. A customer being serviced occupies one or more serving facilities for an amount of time dependent on the location of the case and the type and amount of service required. Accordingly, new customers may arrive in the system and have to wait (in a queue) until an appropriate resource is available.

The simulation is keyed to specific events, such as the arrival of cases requiring service, completion of service by one or more assigned resources, interruption of service by an assigned resource which must be reassigned to a case of greater severity, etc. Consequently, operation of the program proceeds from one significant event to the next, with an internal clock keeping track of the passage of simulated time. Figure II-5 and the following summary description of SARSIM processes provide a guide to the model's use.

SARSIM is comprised of three major program packages; namely, the Preprocessor (PREPRO), Operational Simulator (OPSIM), and the Postprocessor (POSTPRO). One or more of these modules may be employed to explore a particular set of conditions.

PREPRO prepares data for simulation runs by extracting information from magnetic tape files of actual cases served by individual Coast Guard Stations. The data extracted includes types of emergencies, severity of cases, characteristics of personnel or property involved, weather and sea conditions, number and kinds of services rendered for search and/or assistance, etc.

PREPRO is designed to be used in either of two ways. The user may choose to validate the model using historical cases in their historical sequence. This mode of operation should be used periodically for continuing validation. More often, however, PREPRO will be used to generate a random sequence of historical cases to simulate a workload for some specified point in the future.

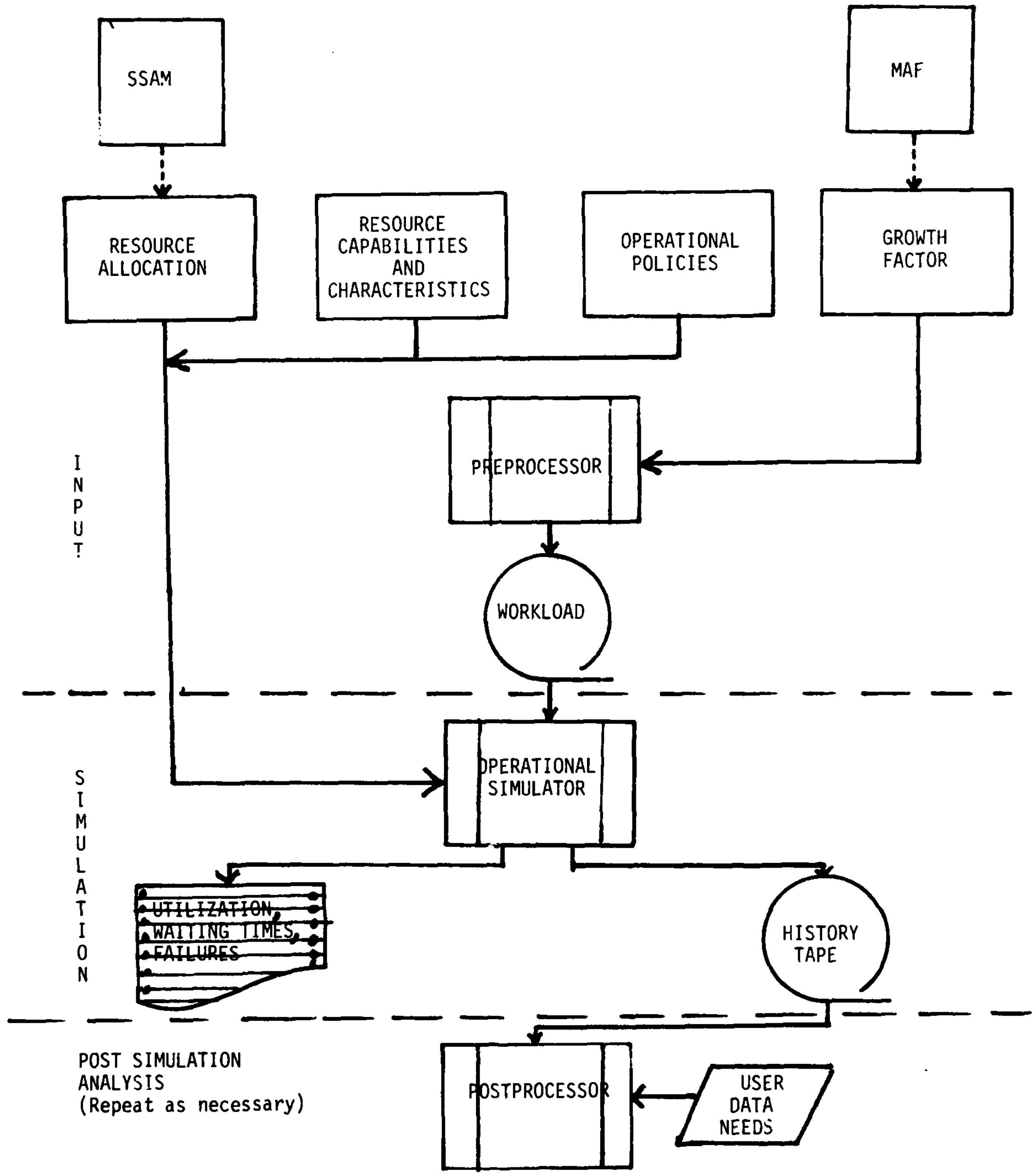



FIGURE II-5

SARSIM: INPUT-OUTPUT

This technique can account for anticipated increases or decreases in future workload. If desired by the user of the simulation, attention can be paid to specific kinds of variation in demand for services, including general or specialized growth. For example, cases may be injected to reflect new types of service demands and specialized peak loads. It should be observed that the same workload may be re-used for as many runs as one chooses with variations in other inputs.

The heart of the Simulation Model, OPSIM, accepts demand schedules for service from the PREPRO, assigns resources, and measures how well services are supplied. This is done under the control of the following critical inputs which can be varied by the user to capitalize on the wide-ranging flexibility of the model:

(1) Capabilities and characteristis of each type of resource employed, including endurance, hourly operating cost, relative cost, speeds achievable in various operating modes, time to refuel, reliability and maintainability, and associated time required to get underway.

(2) For each unit in the district

(a) A geographic location

(b) The number and type of vehicular resources assigned

(c) The crew manning levels for each shift, and

(d) A list of nearby stations, aircraft and ships that can assist with that unit's workload.

(3) Operational policies, especially with regard to the degree of interaction between nearby units.

In addition to the above inputs, the user provides OPSIM with certain system performance standards such as tolerance times for each severity level.

These times are the maximum acceptable time until a resource arrives to provide service to a client in distress. Once the demand, resource, and operational policy inputs have been prescribed, OPSIM operates on the cases and keeps track of pertinent statistics.

At the completion of the operational simulation a file may be prepared on tape of the various case attributes for subsequent analysis within the PostProcessor. In addition, OPSIM also generates a printout of the following:

(1) District Statistics:

(a) Number of cases which occurred; number of cases completed; the number of failures caused by a lack of suitable resources in the system or at primary and adjacent stations; and the number of times the system failed to satisfy prescribed tolerance times.

(b) Average utilization statistics overall, by shifts, and by resource types; of boats, cutters, C-130's, and other aircraft.

(c) Number of standby callups and how many were unproductive.

(2) Station Statistics:

(a) Counts of cases for which resources from a given station were assigned to cases or were first to arrive on scene; failures of the types listed in (1) (a).

(b) Number of queues; number of interrupted services.

(c) Average time for resources to transit to cases; average waiting time for clients awaiting service; average waiting time for only those cases when tolerance exceeded; and, finally, average of time in excess of tolerance.

(d) Miscellaneous station statistics, including calculation of a standby call-ups, unproductive call-ups, and utilization figures.

(3) Group statistics within the district, similar to those for stations.

(4) Resource statistics, including number of times assigned and average utilization indices.

(5) Attributes of exceptional cases, such as any needs which cannot be met with any available resources.

(6) Utilization statistics and average times, segregated by weekday and weekend, similar to those for stations

(7) Lists of cases remaining in queue and all busy resources at the end of the simulation.

THE POSTPROCESSOR (POSTPRO)

The foregoing list of the OPSIM outputs illustrates how the data presented, although fairly detailed, are to a considerable extent aggregated over what might easily be a large number of quite varied cases. The function of POSTPRO is to enable the user to acquire statistics of interest for a more highly selected group of cases. To this end, the details of individual cases may be accumulated on tape by OPSIM for manipulation within POSTPRO.

POSTPRO has what is termed "QUICK QUERY," a computer routine which enables the user to specify classes of cases of special interest (such as cases occurring in a particular geographic area or at a given minimum distance from shore), as well as formulae for desired calculations and the output format.

The output of SARSIM is in terms of measures of performance. Management responsibility is directed toward allocating its limited resources to achieve a desired level of effectiveness measured in terms

of percent attainment of program objectives. SARSIM's performance measures must therefore be converted to levels of effectiveness. This conversion process is an essential element of a total SAR planning process and is discussed in detail in Chapter III.

## CHAPTER III - SAR PLANNING PROCESS: AN EXPANDED CONCEPT FOR DYNAMIC DECISION MAKING

The previous chapter described three new planning tools. That description was mainly concerned with the inputs and outputs of the individual aids and made only general references to their systematic use for planning purposes. Chapter II was written with the implicit assumption that the tools would be assimilated into an existing planning system.

The Study Group has been deeply involved in the SAR program for several years and has gained considerable management insight into the SAR decision making process. In late 1967 Figure III-1 represented the best available perception of what that process should be and served as a basic frame of reference for the development of the tools produced by the study. During the SC&FA, the concept of SAR decision making matured and ripened. In particular, the conceputalization has been enhanced by explicitly treating the role of planning in SAR decision making.

This orientation is reasonable from several viewpoints. First, decisions are made only about future activities. Since the future is uncertain, estimates must be made of what is likely to occur and what corresponding action should be taken. This is planning. Second, because estimates are made of both future events and the effects of future planned action, it is necessary to plan for review of these estimates. Such review will enhance future estimates.

Figure III-2 is a macroscopic view of the SAR planning process. The remainder of this chapter will "flesh out" this skeletal representation

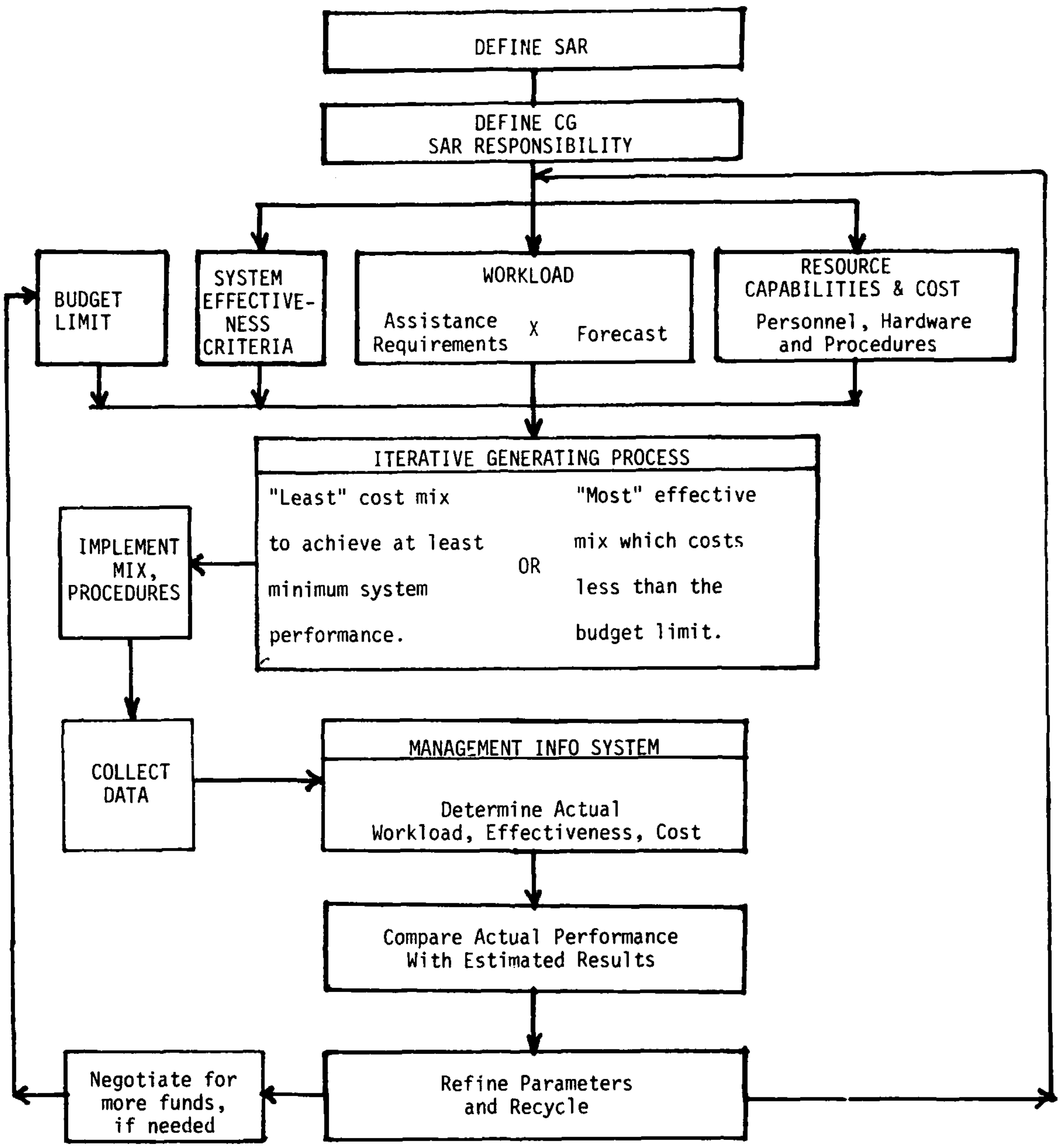



FIGURE III - 1

SAR DECISION MAKING PROCESS

and show the key roles that the newly developed tools play in the process. Some insights gained from the recent study of multi-program requirements for aviation resources are included.

## A. The Definition and Prediction Stage

The purpose of planning is to identify what techniques and resource allocations (personnel and equipment) are required to meet the needs of our clientele at some point in the future. The first order of business

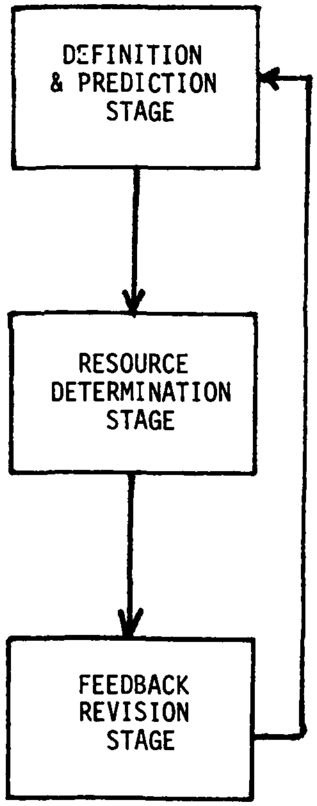



FIGURE III - 2

SAR PLANNING PROCESS (MACRO)

is to define both the program and the clientele for which we are responsible. This was covered in the first interim report and is summarized in Annex A of this report.

In order to make reasonable estimates of future force levels, reliable predictions are a must. In these times of accelerated change forecasting is especially difficult because the past is much less prologue and much more history. Simple linear extrapolation of the recent past rarely provides adequate anticipation of the long range future for which major capital acquisitions are made. Thus, forecasting expertise is vital to the planning function. Consequently, an expert forecast methodology for predicting marine activities was developed. The planning process is used to translate the forecast of the environment into the need for, and use of, resources.

The first translation step is to identify those environmental activities that will help predict the work to be done in a program at some specified point in the future. This selection process is in essence a heuristic one in which the program manager uses his experience in hypothesizing which activities can reliably predict SAR incident levels. These hypotheses can be tested by statistical analysis of observed data. This testing involves evaluating several different relationships to see how well each fits the observed data. The better the fit, the more reliable the prediction is within the limits of accuracy specified in the tests.

The foregoing illustrates how a forecast of marine activities can be used to predict program incidents. In the case of SAR, an initial set of these relationships is contained in the Marine Activities Forecast. Improved relationships for estimating SAR incident levels can be determined by the program manager on each repetition of the planning cycle.

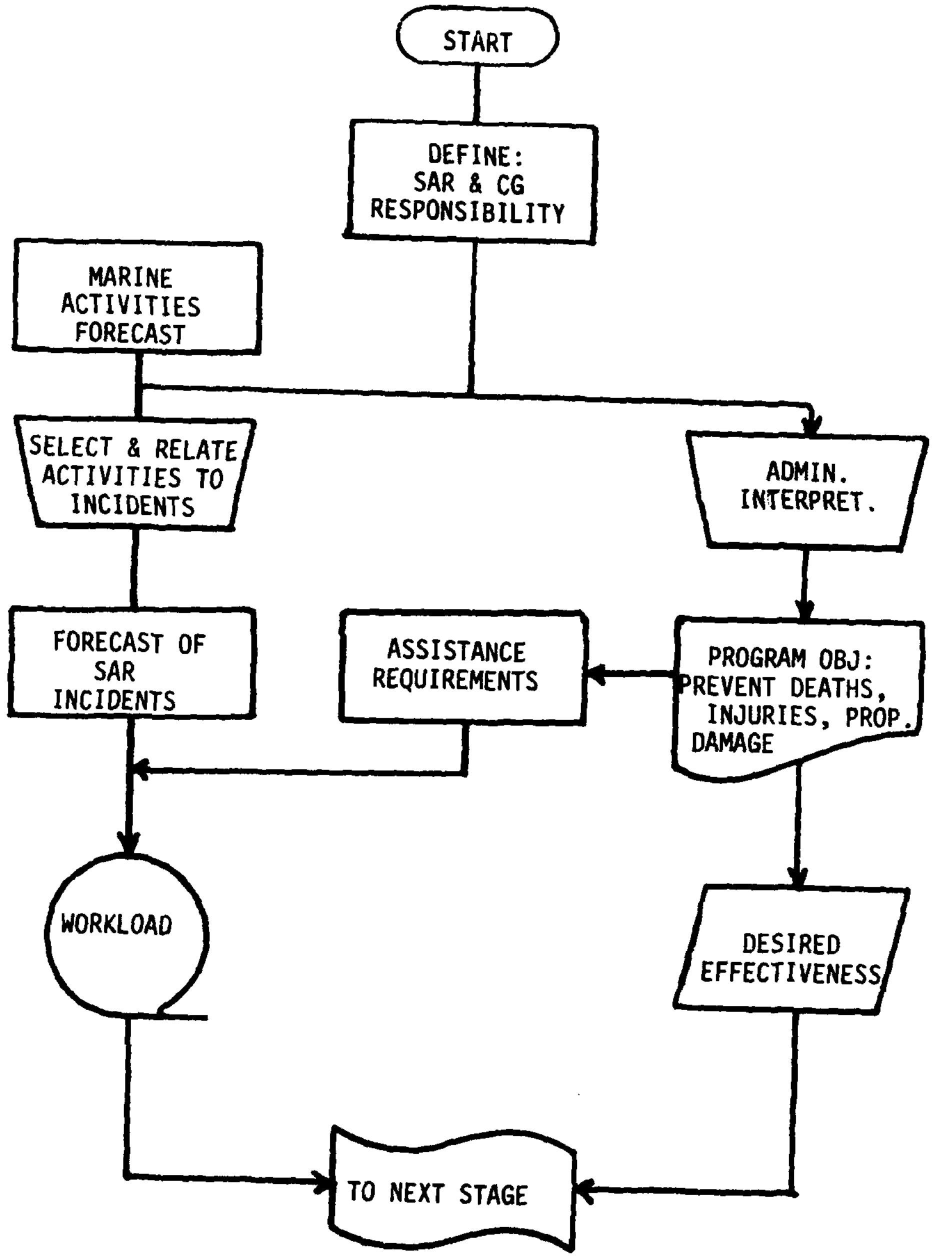



FIGURE III-3
DEFINITION AND PREDICTION STAGE

The statutes that define Coast Guard SAR responsibility are purposely general in nature. There is much room for administrative interpretation which is manifest in at least three ways. First, the general guidance furnished by Congress is used by the program manager to specify program objectives, i.e., prevention of deaths, injuries, and property damage. Second, the program manager determines what efforts are generally needed to accomplish those objectives. These efforts have been termed assistance requirements and when multiplied by the forecasted incident levels yield the projected SAR workload. Third, the program manager interprets the intent of Congress and the will of the people in judging how much of the program objectives are realistically attainable. In the words of the Long Range View, "Response to public demand...will be effected within a framework of acceptable tolerance...with awareness of the unrealistic expense of 100 percent response capability." The complement of acceptable tolerance is a desired level of effectiveness where effectiveness is defined as benefits achieved divided by objectives sought.

The above description of the Definition and Prediction Stage of the SAR Planning Process is sketched in figure III-3. Note that workload and desired level of effectiveness are inputs to the next stage.

B. Resource Determination Stage

Chapter II described SARSIM as needing four inputs (workload, operating tactics, resource allocation and resource capabilities). It also indicated that the outputs would be evaluated against some type of cost constraint and a set of minimum performance standards. The cost comparison is necessary because there are limits on the availability of funds.

The use of minimum performance standards to gauge the merit of alternative resource allocations is not in consonance with the SAR Program Definition contained in CG-411. The Definition states that "effectiveness of the program must be measured in terms of how well the program accomplishes [its objectives]." Comparing measures of resource utilization and client waiting times with minimum acceptable values for those items does not address how well we are accomplishing the task of preventing deaths, injuries and property damage. The appropriate measure of effectiveness is the ratio of losses prevented to losses that were there to be prevented. Such a measure has not been used for planning because the conversion from output performance (i.e., resource utilization) to benefits achieved (i.e., losses prevented) has not been developed. Experience in other program areas (ELT, for example) has shown that resource allocations based solely on minimum performance standards do not, in general, achieve satisfactory levels of effectiveness. In essence, this means that resource allocation must be based on a desired level of effectiveness which will in most cases be greater than the effectiveness level associated with a given set of minimum performance standards.

Minimum performance standards are analogous to the amount of fuel consumption necessary to place a vehicle in motion. Less fuel can be used but you may not go anywhere. On the other hand, desired level of effectiveness is akin to the fuel consumption at the most economical speed. More fuel can be consumed and greater speed will result but the cost per unit distance will be greater.

Using effectiveness as one criterion for determining the adequacy of resource allocation permits the use of minimum performance standards

as a fifth input to SARSIM. There it will be used to help in the assignment of resources to cases.

In view of the above, the Resource Determination Stage can be characterized as possessing three steps.

(1) simulating performance

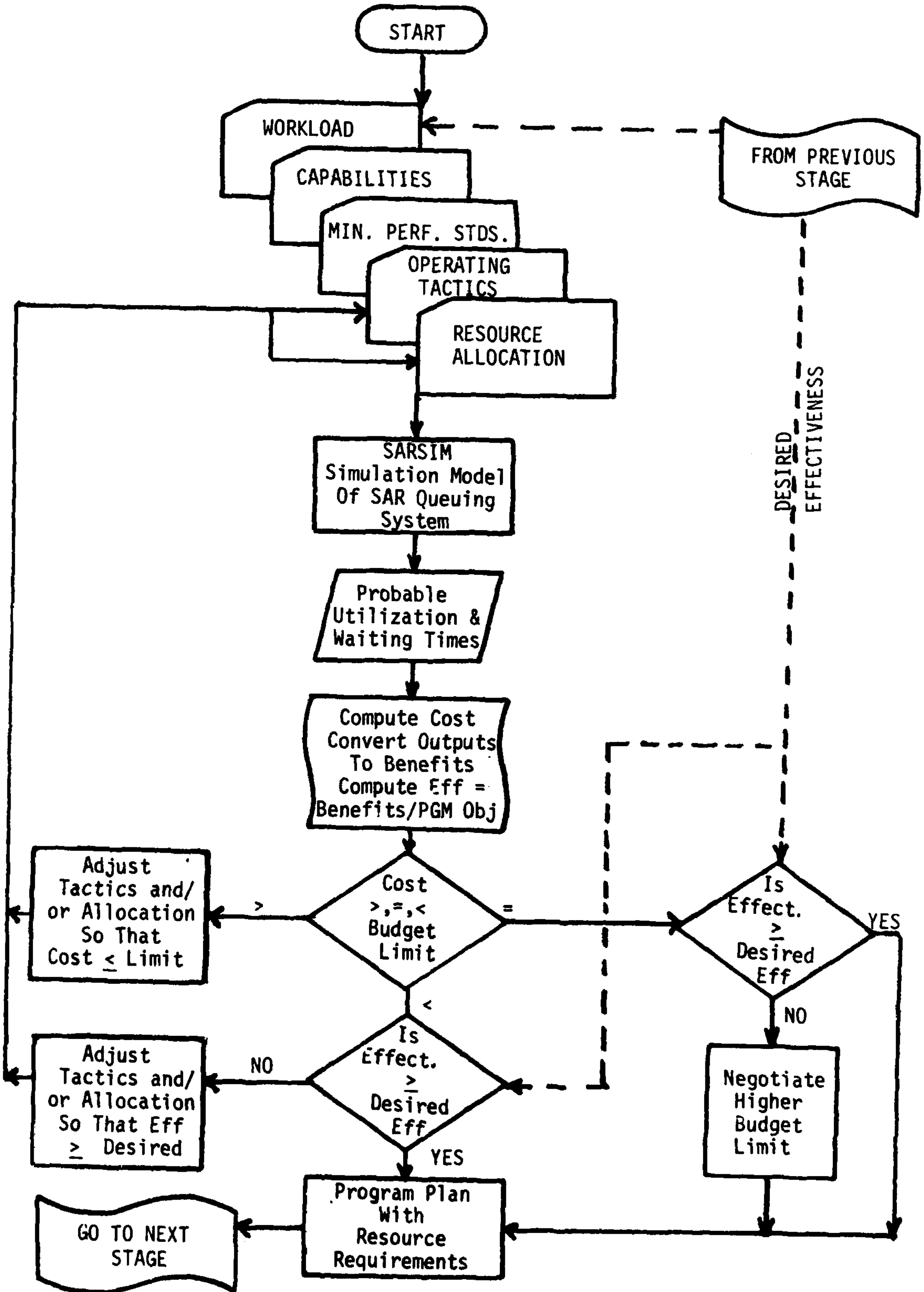
(2) converting outputs and computing cost and effectiveness, and

(3) evaluating the acceptability of the costs and effectiveness and recycling until the system reaches its most acceptable state within the limits imposed.

This stepwise procedure is the same as that described in the previous chapter with the exception that now SARSIM has five inputs and the outputs are converted to benefits thence into effectiveness for evaluation of system acceptability. Figure III-4 is a diagram of this stage. The finally arrived at resource requirements become the heart of the program plan are and inputs to the budgeting cycle.

It should be noted that documentation of our inability to reach the desired level of effectiveness during the planning phase because of a budget limit is excellent bargaining ammunition for use in negotiating a higher limit. Further, documenting the inability to reach a desired level of effectiveness after the fact is also a strong argument but of little consolation to the already disadvantaged client. This involves what is frequently called feedback checking and leads us to the next stage.

FIGURE III-4 - RESOURCE DETERMINATION STAGE



C. Feedback and Revision Stage

Because the planning process that leads to a set of resource allocations is in large measure based on estimates and judgmental evaluations, one needs to check these estimates and evaluations by comparison with actual operations. Hence this stage involves data collection from the field followed by an analysis which looks for deviation between planned and actual operations. The intent of this analysis is not to force compliance with plans but rather to learn how to plan better so that operations may proceed even more efficiently.

The information that needs to be collected can be divided into five categories:

(1) utilization of resource & client waiting time statistics,

(2) benefits achieved,

(3) incidents occurring,

(4) activities occurring, and

(5) expressions of client (dis)satisfaction.

Because SAR is a queuing system, data concerning client waiting times are invaluable in managing the system. The waiting time from the client's point of view commences when he becomes aware of his problem and terminates when a resource arrives at his location. Because information available concerning the actual time of occurrence is poor, the Coast Guard calculates waiting time as the interval from time of notification to arrival on scene. This exclusion of the communication lag is a temporary expedient that has a serious side effect. It creates an artificially high performance measure which can lull us into being satisfied with the communications lag. Analysis directed at reducing

this lag may well result in lower operating costs by changing the current practice of using multiple resources of higher speed.

Resource utilization is multifaceted because there are various types of resources and crew manning procedures. At shore stations where crews are in general interchangeable with boats, there is a need to identify the utilization of the boats and crews separately. For air stations and floating units the utilization of the vehicles remains straight forward, but the utilization of the crew(s) is complicated by the concept of standby and recall. For example, how much should the requirement to remain in a recallable status count toward determining the crew(s) work-week?

The benefits achieved are lives saved and deaths, injuries and property damage prevented. As discussed in CG-411 the former is directly attainable from current reports. The remainder must be estimated. The method of estimating is amenable to data analysis.

The incidents occurring (and the attendant loss of life, prevention of deaths, etc.) include not only SAR cases handled by the Coast Guard, but also those distress events in our area of responsibility of which we are unaware. Consequently, data sources other than assistance reports must be tapped in order to develop more complete information. Some appropriate sources are accident reports, insurance company claim files, and newspaper articles. Some of the incidents reported by other sources are already included in the assistance report file so screening for multiple counting is necessary. Although this additional work will not result in a complete tabulation of all incidents, the expected gain will be significant and will result in a more accurate measurement of effectiveness.

Obtaining more complete data concerning marine activities will involve interagency cooperation. On the other hand, some pertinent data is readily obtainable from the latest edition of the Statistical Abstract of the United States published annually by the Bureau of the Census. This source also lists other valuable data sources.

Finally, indications of client (dis)satisfaction are received irregularly and often outside of routine channels. Communications of dissatisfaction are helpful because they can provide early warning of poor performance. However the complaint of an individual obviously needs to be weighed against the tacit approval of the silent majority.

Given all this information how does it help the planning process? Figure III-5 shows the study group's concept of how feedback information should be used to improve the planning process. The sequential order in which the checks are made in the diagram is of no significance. The general approach shown is to use the latest information available to revise, and thereby improve, the estimating procedures used previously.

The assistance requirements used to help describe workload are in large measure the service times needed for each client. If the service times for a large number of clients are grouped by length of time, an estimate of the service time distribution is developed. The most recent information on service times can be used to improve this estimate of service time distribution.

The next check might be to determined the relationship between queuing statistics and the benefits achieved and update the conversion of outputs to benefits used in the second stage.

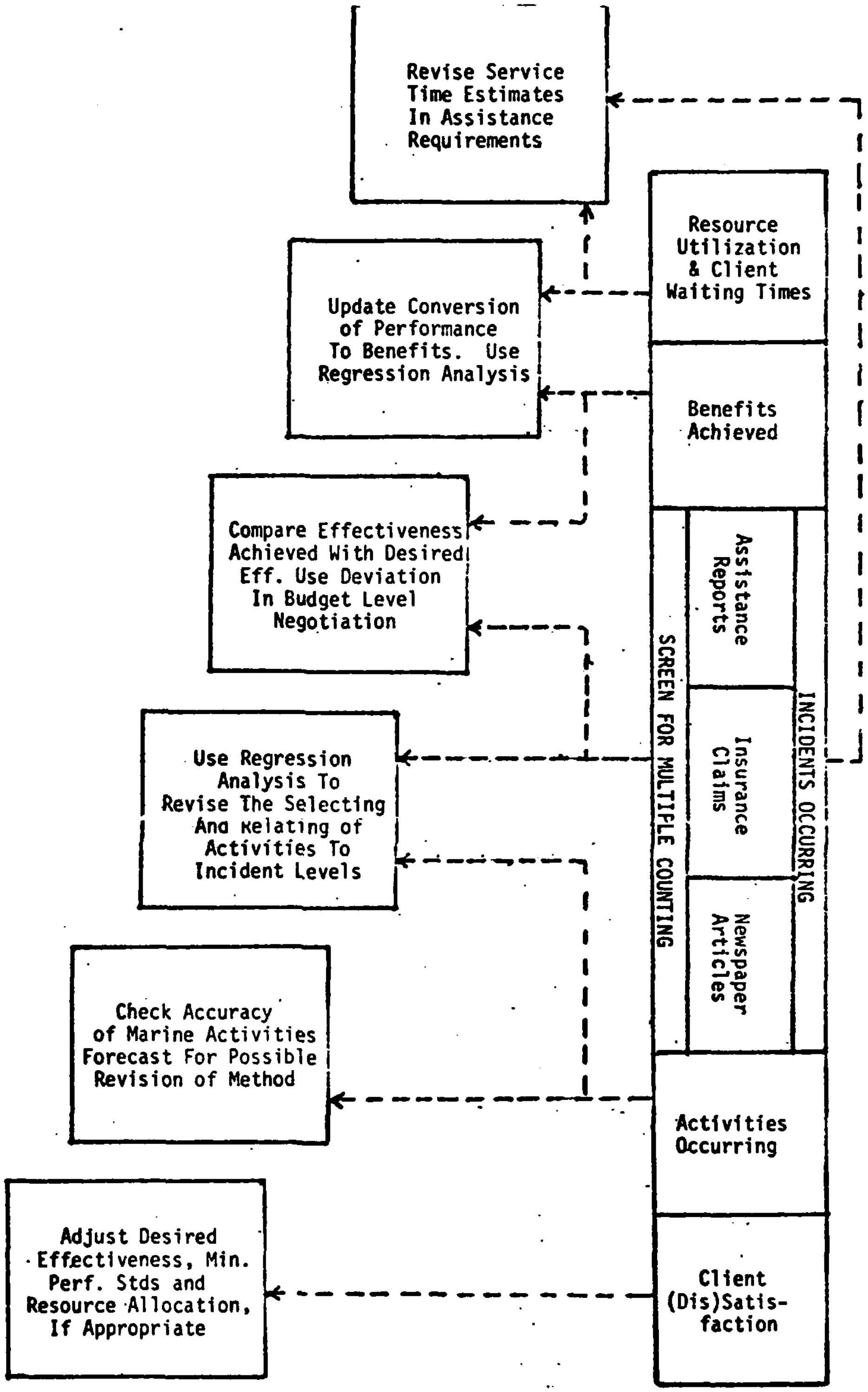



FIGURE III - 5
FEEDBACK AND REVISION STAGE

This third check computes the effectiveness achieved and compares it with the desired level of effectiveness. Any deviation here provides strong arguments for a change in resources as mentioned earlier.

The relationship estimated previously between levels of certain marine activities and SAR incident levels should be reestablished using the new additional information. Again, regression analysis seems appropriate. However this time multiple regression is indicated, so that the activities that best predict incident levels can be identified as well as the relationship.

Next the actual activities are compared with those predicted by the Marine Activities Forecast. A significant deviation will suggest the need to adjust the forecasting methodology.

The final check is a review of the desired level of effectiveness, minimum performance standards and resource allocations in the light of expressions of client (dis)satisfaction.

## CHAPTER IV: IN CONCLUSION: SOME RECOMMENDATIONS

This report concludes the multi-year SAR Criteria and Force Analysis. Previous chapters have described the tools developed and a dynamic SAR Planning Process into which they can be assimilated.

As important as these new tools are, their contribution to the manager will only be as good as the continuing supplemental analysis that integrates them into an improved planning system. Toward this end, this chapter recommends areas where additional analysis is required to make the SAR Planning Process a viable reality.

### A. LONG RANGE FORECAST OF ACTIVITIES IN THE MARINE ENVIRONMENT

It is recommended that:

1. The Forecast be updated on a continuing basis and at least annually by collecting pertinent information from sources both inside and outside the Coast Guard.

2. The updating of marine activity projections remain within the purview of the Chief of Staff because the forecasts are applicable across many programs.

3. The program oriented implications drawn from the projected activity levels (i.e., the functional relationship(s) between activity levels and program incident levels) be revised by the respective program managers at least annually.

4. Sensitivity analysis be conducted on the point estimates made in the Forecast, thereby assessing the impact of an error in those estimates.

## B. SHORE STATION ANALYTICAL MODEL

It is recommended that the model's applicability be expanded to include those stations having a seasonal workload of less than 34 serious cases. This involves the use of a variable MAR factor of 1/total number of serious cases or 3%, whichever is larger.

## C. SEARCH AND RESCUE SIMULATION

It is recommended that SARSIM be exercised extensively for at least one year (until 1 July 1972) without major alterations. This "break-in" period will thoroughly familiarize the user with the model's capability and permit him to gauge the model's predictive reliability.

## D. SAR PLANNING PROCESS

The crux of planning is the prediction of future events and what resources are needed to satisfactorily cope with these events. Unfortunately, not all future events are easily predictable. A relationship must be established between the events of interest and those that can be predicted. The Marine Activities Forecast provides a relationship between predictable marine activities and events of interest; namely, SAR cases.

In order to efficiently plan for future resource needs, it is necessary to know what effect a change in level of effort has on the system's ability to cope with the events of interest.

As stated in CG-411 the effectiveness of the SAR program (i.e., degree of success in coping with events of interest) must be measured in terms of how well the program accomplishes the task of rendering aid to persons and property in distress. It goes on to say that SAR program benefits are measured in terms of deaths prevented, property loss prevented, and injuries prevented. Because the second and third benefits above are difficult to quantify and of lesser importance than the first, the Program

Definition's use of deaths prevented as the sole measure of benefit is concurred in. Furthermore, as argued earlier, effectiveness is defined as:

$$\frac{\text{benefits achieved}}{\text{benefits achieved + benefits unattained in CG areas of responsibility.}}$$

What is required then is a means of evaluating the effectiveness of any level of effort. In other words, what relationship exists between resource utilization and deaths prevented?

SARSIM provides major insight into this specific relationship. It shows for a given workload and resource allocation how often, how long, and which severity of customers must wait for assistance. What remains to be developed is the relationship between client waiting time and the probability of a customer dying. This permits the calculation of effectiveness which must then be evaluated by the program manager to ascertain whether or not it falls in his zone of acceptability. The upper limit of this zone is <u>ideally</u> determined as the point at which the increase in effectiveness of an efficient allocation of resources is worth less than the cost of achieving it. The lower limit is the effectiveness associated with satisfying minimum performance standards. Budgetary limits may force the manager to accept an effectiveness level lower than the upper limit. The practical limitations associated with quantifying the upper bound of the acceptable effectiveness zone are acknowledged. Nevertheless, the requirement remains for the program manager to state how much is enough. It is in establishing the upper and lower bounds of the acceptable region that the decision maker can best use his judgment in assessing the political climate, public will and the intent of Congress.

Accordingly, it is recommended that:

1. The concept of the SAR Planning Process outlined in Chapter III be implemented by undertaking the following:

a. Analyze the data collection system in the following manner:

(1) Examine the feedback checking stage to determine the specific information required and its source.

(2) Compare these requirements with the data available.

(3) If necessary, revise the data collection process to delete unnecessary information and obtain additional data not presently available.

b. Part of the information collected should provide the data necessary to analyze client survivability as a function of time in order to establish a relationship between client waiting time and probability of death.

2. The desired level of effectiveness and minimum performance standards be established by the program manager.

The above recommendations have been made in recognition of the complementary mix of intuition and analysis necessary in the decision making process. Intuition has the remarkable facility for identifying the important elements of a problem and suppressing the rest. It can frequently infer the "best" solution; however, it remains for analysis to either prove or disprove the correctness of the inferred "best" solution. Infusion of the three new tools into the existing SAR Planning Process reduces the burden previously placed on the program manager's intuition. The recommended re-structuring of the planning process allows for a balanced blend of both intuition and analysis in order to strengthen our budgetary position in competition for limited resources.

ANNEX A - SYNOPSIS OF STUDY ACTIVITY NOV 1967 - JUNE 1970

This chapter provides a brief summary of the study activities described in previously submitted Interim Reports 1, 2 and 3. The complete reports are available for review in the Plans Evaluation Division (CPE), the Search and Rescue Division (OSR) and the Operations Plans Staff (OS).

A. November 1967 - August 1967

The highlights of this period were:

- the genesis of the study which has been covered in Chapter I of this report.
- the structure for the study
- the results of analysis concerning definitions of
    - Search and Rescue
    - the Coast Guard role in Search and Rescue

1. Structure - It was clear that system analysis on an integrated basis (cutter, shore station and aircraft) of alternative search and rescue forces could provide an overall framework for the planning of the search and rescue mission. The developed analytical capability would also serve to

- reorient Coast Guard SAR planning to an output orientation, and
- provide a basis for integration of previous SAR studies.

The end product of the study was thus conceptualized as "a dynamic, integrated, analytical decision making process for allocation of resources and deployment of SAR forces and facilities."

Figure A-1 is a diagrammatic representation of a systems approach to SAR decision making. It portrayed the framework within which the components to be developed by the study were to be used. A brief explanation of the rationale behind each block follows.

a. Definition of SAR - This involved the specification of the classes of events that constitute the program area. The definitions would be general enough to be meaningful even in times of rapid change.

b. CG Responsibility - Given the results of a., this step would identify the Coast Guard role in coping with all events that are classed as search and rescue. A range of roles would be examined and be presented for decision. The results of these first two steps will be outlined in the next part of this chapter.

c. Workload - was conceived as being two multiplicative factors, namely, the work to be done on an individual incident (Assistance Requirements) and the expected frequency of that type of incident (Forecast).

(1) Assistance Requirements - Groupings of incidents were thought to be practical on the basis of such factors as geographical region, type of distress, clientele, etc. For each grouping the likelihood of satisfying the needs of that group would be determined as a function of alternative levels of effort and alternative time constraints.

(2) Forecasting - would not be limited to extrapolations of historical utilizations. Instead, considerations of demographic factors and potential changes in legislation would be included. Forecasts would be expressed as ranges of values as opposed to point estimates.

d. Demand Satisfaction - would encompass the need satisfying capabilities of hardware (tools) together with the required crews and their

# DIAGRAM OF SAR DECISION MAKING PROCESS

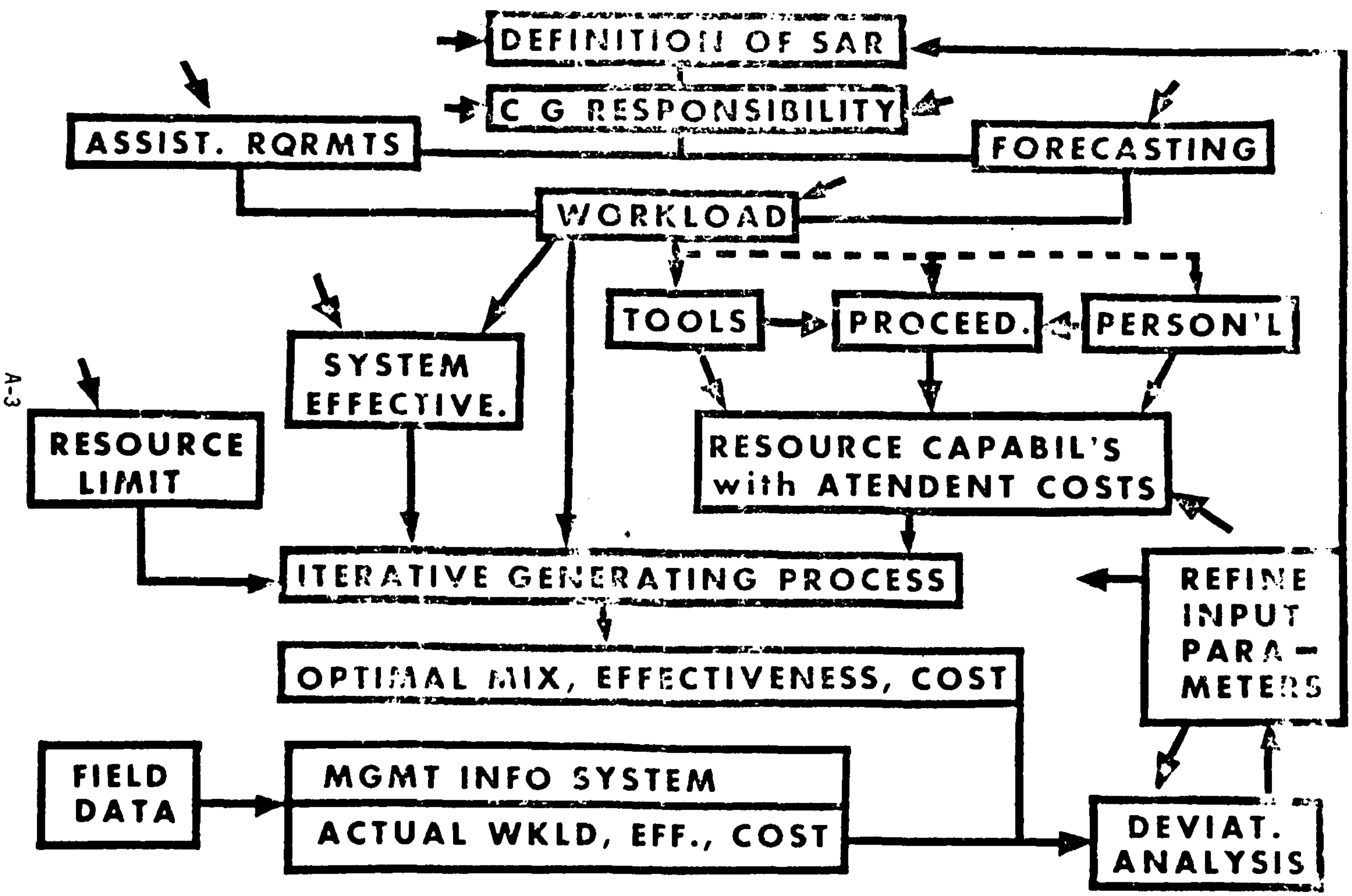



FIGURE A-1

limitations (personnel) and the operating rules for the resources (procedures). Considerations of cost would also be included.

e. System Effectiveness - is a set of criteria against which the performance of the resources would be measured. For SAR these criteria are lives saved (deaths prevented), injuries averted and property damage prevented. As an interim or proxy measure the responsiveness of the system in time units seemed appropriate.

f. Resource Limit - refers to the real world constraints of the budgetary process that generally dictate phased procurements of resources.

g. Iterative Generating Process - Given anticipated workload, resource capabilities and cost, effectiveness measures and budget limits, this process would determine the mix of facilities that can meet the minimum acceptable level of performance at the least cost. If the cost were greater than the budget limit, the process would then seek the mix with the greatest effectiveness for a cost less than the budget limit. It is also possible to alter the procedures in an attempt to remain within the constraints.

h. Optimal mix, effectiveness, cost - No proof of the optimality of the generated mix is likely but an evolution to increasingly better solutions is to be expected. This "better mix" would then be implemented.

i. Management Information System - collects field data which describes the actual needs of clients and the use of resources. Actual workload, effectiveness (performance) and costs are determined.

j. Deviation Analysis - compares forecasted workload with the

actual workload in a feedback loop. If they compare favorably, our projection was well done. It is more likely, though, that adjustments would be needed and the Coast Guard would refine input parameters and forecasting procedures before making another pass through the planning cycle.

2. Results of the Definition Phase - Efforts on this phase began upon Departmental approval of the structure in December 1967.

a. Definition of SAR - the group developed a new definition of SAR that possessed the following characteristics:

(1) Broadness

(2) Output Orientation

(3) Compatible with current practice

(4) Compatible with law

(5) Curative rather than preventative

(6) Clarity

The new definition was compared with several others in various publications. Only the one in the National SAR Plan compared favorably. The study group finally recommended the existing SAR Plan definition because it was time proven, conformed to the criteria above, was well accepted and would pose no disruption to the continuity of SAR.

Although the newer definition might have somewhat clearer meaning, it would have inevitably led to some disruption. Thus, the definition of the SAR Plan was supported as being appropriate for programming purpose.

b. Coast Guard Responsibility - Having determined what comprised universal SAR the next phase of the study was to analyze procedures for the logical development of a Coast Guard responsibility.

The first delimiting factor considered was the natural one of

national sovereignty. The group reasoned that nations would be responsible for SAR in their own territory and handle SAR in space, international waters, etc. on a cooperative, enlightened self-interest basis. There seemed no reasonable alternative.

The parsing of national federal responsiblity admitted of a wide variety of alternative but could be reduced to three basis configurations:

- A Central SAR agency
- A Confederation of agencies
- Independent agencies with independent responsibilities

Originally, the single agency concept was appealing, but it had many disadvantages. Perceived reductions in the current separate agencies would probably generate great antagonism and "in-fighting." Additionally, there is no convenient place to locate such a central agency within the federal departmental structure and there is no public outcry for the unification of SAR. Therefore, the central agency concept was judged to be inappropriate.

A confederation of agencies could provide for more efficient central planning but the lack of a "hammer" to force compliance would cause such an arrangement to be ineffectual. This concept was quickly abandoned.

The remaining alternative was the status quo wherein several federal agencies exercised separate jurisdictions. Since voluntary cooperation has been experienced in the past and it is reasonable to expect that it will continue, the question is, "Who should be responsible for what?"

The military provides SAR for deployed forces. NASA is tasked

with space SAR. The post facto nature of SAR and the state-of-the-art in aviation rescue equipment reduces airborne SAR to the cognizance of the agency with responsibility for the surface on which a distressed aircraft lands/crashes.

SAR activity over the land mass is conducted by a variety of operators. Medical evacuations are conducted by ambulance operators private and/or public. Fire protection is the responsibility of individual fire departments. Persons placed in distress by civil disturbances are the responsibility of local safety officials. Industrial accidents are handled by the industrial activity. Response to highway, rail and pipeline accidents falls within the purview of the associated modal element of the Department of Transportation. Therefore, a logic exists for the multipartite division of land SAR responsibility.

There exists a class of incidents that are few in number, but have very far reaching effects when they occur. Incidents such as earthquakes, hurricanes, tornadoes and floods are in this category. The nature of these events is such that no one agency has the capacity to meet the need. Coordinated activity of all available resources to meet the crisis is needed at the time the event occurs. The Office of Emergency Planning has been changed with the overall coordination that is a necessity for this type of incident where the use of all available forces having a potential to help is required.

The previous apportionment of responsibility leaves one final area for consideration, i.e., activity on, over and in the water area subject to the jurisdiction of the United States and that international water

area where the country has agreed to provide SAR service. This includes those military activities conducted in this environment as a common carrier. The foregoing has been the traditional responsibility of the Coast Guard.

The analysis group recommended that no change in Coast Guard search and rescue responsibility be made. This was agreed to by Coast Guard and Departmental officials and delimited the class of incidents that the group would analyze.

B. SEPTEMBER 1968 - JUNE 1969

In order to improve SAR system effectiveness, as measured by the ratio of lives saved (deaths prevented) to the number of persons in distress, it would be necessary to convert some potential deaths into lives saved. An analysis of accident reports resulted in the conclusion that, given existing technology, few if any of the lives lost were amenable to rescue by a reactive SAR force! It was further concluded that when required, a moderate extension of time for the first unit to arrive on scene would not significantly degrade the chances of rescue in most cases.

Analysis of the SAR workload revealed that a substantial majority of cases were first serviced by a boat from a shore station. It was also seen that most of these stations operated relatively independent of one another. Additionally, the aggregate operating cost of the shore stations was significantly higher than either cutters or aircraft. Consequently, initial efforts were devoted to the study of the shore stations.

A mathematical queuing model was developed to measure the effect of alternative force levels on service. This effect was expressed in probabilistic terms, namely, the expectation of not immediately serving a serious SAR incident. The model was applied to individual units and

their respective workloads were predicted by the newly developed Marine Activities Forecast.

The model determines the minimum force levels needed to keep the probability of a serious case waiting below a specified maximum (maximum allowable risk). This is in consonance with the "acceptable tolerance" concept contained in the Long Range View.

The arguments for adoption of such a force determination methodology were sufficiently appealing, that a field test using a maximum allowable risk of 3% was approved by the Commandant and instituted in the Boston area in February 1969. The results of this initial test were so encouraging that further tests at selected shore units on a service wide basis were directed at the earliest reasonable time.

The Boston test indicated that at SAR Shore Units in that area, the average workweek could be reduced significantly.

Examination of available system slack should be made to assure that adequate staffing is provided to accomplish all other mission and support tasks.

C. JULY 1969 - JUNE 1970

The study effort was divided into four final subtasks:

(a) automation of the shore station model and determination of the sensitivity thereof,

(b) adaptation of the shore station model methodology to other resource types,

(c) marine activity forecast, and

(d) development of a simulation model for the entire SAR system.

A closed form mathematical model of the Search and Rescue queueing conditions at individual shore stations was automated. It operates on historical data and is used as a management tool in developing readiness postures.

Sensitivity analysis of the shore station model indicated that the output for a station (in terms of required operational readiness) varies directly with total service time and apparent severity of the cases processed by that station. The output also varies inversely with the maximum allowable risk. The model's conservative approach has probably been extreme, especially in the determination of apparent severity for all stations and in the treatment of stations with low workloads and long average service times. There is some evidence that an increase in the maximum allowable risk can be contemplated, at selected sites, in order to overcome this conservatism. However, it is considered imprudent to do so until the model's predictions have been validated by widespread field usage. Such verification will permit the program manager to remove some of the conservatism with increased confidence that Coast Guard clientele would be minimally affected by such adjustment.

Adaptation of the shore station model to other homogeneous resource types was attempted, but was determined to be unrealistic.

The forecasting effort of the National Planning Association was altered to reflect:

(a) greater emphasis on the period to 1980 (with some implications to the year 2000).

(b) data collection and projection at the micro level (counties) with several echelons of subsequent aggregation.

(c) expanded explanation of the socio-economic techniques employed to facilitate both use of the results and periodic future updating of the forecast.

The results are in two parts. The first is a general forecast of various activities in the marine environment. It is expected to have significant planning value for other Coast Guard mission areas. The second relates these activities to the expected SAR workload.

The major study group effort during this period was the conceptualization of a computerized simulation model (SARSIM) that investigates the dynamic SAR system on a multi resource, district-wide, interactive basis. This was a joint endeavor by the Coast Guard and the Technical Analysis Division of the National Bureau of Standards. The model operates on a historical data base under user specified conditions. SARSIM permits the manager to assess the expected impact of changes in resource allocation, patrol activity and operating rules.